DOCUMENT RESUME

ED 417 985 SE 061 330

AUTHOR Rea-Ramirez, Mary Anne; Clement, John
TITLE In Search of Dissonance: The Evolution of Dissonance in Conceptual Change Theory.
PUB DATE 1998-04-21
NOTE 29p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (71st, San Diego, CA, April 19-22, 1998).
PUB TYPE Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Cognitive Dissonance; *Cognitive Processes; *Concept Formation; *Conflict; Elementary Secondary Education; Knowledge Representation; Learning Strategies; *Learning Theories

ABSTRACT

One problem in the field of conceptual change theory is that disparities occur with respect to the meanings of the terms "conflict," "disequilibrium," and "dissonance." As the strategies aimed at conceptual change have evolved, the same terms have taken on new meaning. This paper aims to present a brief review of the evolution of conceptual change concepts particularly as they relate to the terms "conflict" and "dissonance," to propose some additional distinctions and attempt to define terms for them in a consistent way, and to suggest that dissonance can play an important part in conceptual change strategies. Contains 53 references. (Author/DDR)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 417 985

M-Rea-Ramirez

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

IN SEARCH OF DISSONANCE: THE EVOLUTION OF DISSONANCE IN CONCEPTUAL CHANGE THEORY

Mary Anne Rea-Ramirez and John Clement

University of Massachusetts, Amherst, USA

Paper presented at the Annual Meeting of NARST
April 21, San Diego, CA

ED 401330

BEST COPY AVAILABLE

In Search Of Dissonance: The Evolution Of Dissonance In Conceptual Change Theory

Abstract

A problem in the field of conceptual change theory is that disparities occur with respect to the meanings of the terms 'conflict', 'disequilibrium', and 'dissonance'. In addition, as the strategies aimed at conceptual change have evolved, the same terms have taken on new meanings and some new implicit distinctions have emerged. The goal of this paper is threefold: 1) to present a brief review of the evolution of conceptual change concepts particularly as they relate to the terms conflict and dissonance, 2) to propose some additional distinctions and attempt to define terms for them in a consistent way, and 3) to suggest that dissonance can play an important part in conceptual change strategies and to evaluate its most useful role. It is our hope that developing a somewhat richer set of differentiated concepts will lead to better discussion and communication. We argued for using a fairly broad concept of "dissonance" as a sensed disparity between an existing conception and some other entity. This can occur in mild as well as strong forms, as opposed to the concept of "conflict", which suggests only a strong disparity.

In Search Of Dissonance: The Evolution Of Dissonance In Conceptual Change Theory

Introduction

Strategies to foster conceptual change have often driven the definition of terms used in the field. This presents a problem in the field of conceptual change theory since disparities are found to occur with respect to the meanings of certain of these terms such as 'conflict', 'disequilibrium', and 'dissonance'. As the strategies aimed at conceptual change have evolved, the same terms have taken on new meanings and some new implicit distinctions have emerged. The goal of this paper is threefold: 1) to present a brief review of the evolution of conceptual change concepts particularly as they relate to the terms conflict and dissonance, 2) to propose some additional distinctions and attempt to define terms for them in a consistent way, and 3) to suggest that dissonance can play an important part in conceptual change strategies and to evaluate its most useful role. It is our hope that developing a somewhat richer set of differentiated concepts will lead to better discussion and communication.

The strategies to foster conceptual change are most often based on a Piagetian theory of cognitive development in which disequilibrium, dissatisfaction or discord within the individual, must be created between the initial conception of the child (one not in line with scientifically acceptable facts) and the conception to be taught. From this inception, numerous strategies have been proposed, from strict elimination of prior conceptions, to development of dual conceptions operating at various times within the same person as dictated by the situation. In other situations the alternative conception is left unchanged but new knowledge is separately constructed by the individual. For the

purposes of this paper, we will concern ourselves only with those instances where an existing conception is present or is formed during teaching.

Numerous theories exist concerning how conceptual change actually occurs. We will review some of these so as to more fully understand how the vocabulary developed. The work of Vosniadou & Brewer (1987) stated there were actually two types of restructuring which take place during conceptual change. The first, weak restructuring, allows new information to be accumulated and new relationships to occur between existing ideas, without change to the core concepts. This is similar to Piaget's assimilation where new information is integrated into an already existing schema without the necessity of overhauling the basic conception. However, for the second type of restructuring, radical restructuring, to occur, a change in core concepts and structure of knowledge must take place.

Duit (1995) suggests that conceptual change has to do with restructuring what is already known. This view is supported by Piaget, Toulmin (1972), and Jung (1993). Another view was posed by Linder (1993) and Marton (1981) in which they stressed that new ideas are related to the context in which they are used. Marton stated that conceptual change is achieved through an enlargement in context rather than a change in the concept. However, Hewson & Hewson (1992) suggest that it a change in the status (significance a learner assigns a conception) given a conception that allows for a change in the concept rather than just a change in context.

The two categories of weak and radical restructuring were supported by the work of Duschel (1992) who further emphasizes that radical restructuring requires the learner to acquire new procedural knowledge with which to reevaluate existing knowledge before change can occur. Therefore, if students do not have the necessary knowledge base or factual information needed to critically evaluate their existing knowledge, then this radical restructuring may not occur. Still others state that conceptual change occurs when there is a gradual introduction of the necessary new

information, reinterpretation of existing alternative conceptions and exposure to new models that does not promote extinction of the old conception (Vosniadou, 1994; Caravita & Hallden, 1994; Grandy, 1990).

Clearly, conceptual change has been described in a variety of ways. For purposes of this paper, the most useful path for us has been to use conceptual change to refer to situations where a significant new cognitive structure is created - a change that is structural or relational in character. This might happen by modifying a prior conception or model used to understand the target domain, or it might happen by constructing an independent new conception or model. This is compatible with the terminology used by Thagard (1992). For the purposes of this paper we will also use the following definitions:

'Preconception' refers to a conception held prior to instruction in a particular topic.

'Alternative conception' (misconception) refers to those conceptions that are incompatible with currently accepted scientific conceptions.

'Naive conception' refers to those conceptions students hold that, while not incompatible with currently accepted theory, are simplistic conceptions that are not scientifically complete from an expert's view.

'Prior model' refers to either an alternative conception (misconceptions) and naive conception or an intermediate model, as developed during instruction, that the student brings to the learning situation.

We find these categories useful even though they are not mutually exclusive.

We also focus on cases where the student has a prior model that provides an interpretation of a target problem or domain. We also make the assumption that during learning, the prior model is either eliminated, transformed to a different schema, or left untouched. diSessa (1988) has argued that other changes of a more subtle and intermediate nature can occur (such as a change in the conception's priority or range of

application). This and other more complex models of such cases will be left for future research to consider.

Early Work On Conceptual Change

The earliest literature on conceptual change centered on cataloging students' "scientific misconceptions"; that is, what children actually believed about a subject (Viennot, 1979; Driver, 1973; Nussbaum, 1979; Nussbaum & Novak, 1976). As researchers then began to look at how one would go about helping students move from their misconceptions to a more scientifically accepted conception, they relied initially on Piaget's theory of disequilibrium in which assimilation and accommodation play major roles. Researchers believed that in order for change to take place, disequilibrium in the form of dissatisfaction with the current model must occur (Posner, Strike, Hewson, and Gertzog, 1982). They further believed that once dissatisfied, the student must see the new concept as intelligible, plausible, and fruitful. The student may also need to make changes to other related schemata.

What follows is a discussion of some of the ensuing methods employed in conceptual change research. We will attempt to trace the role of dissatisfaction in these theories of conceptual change.

Elimination Of Alternative Conceptions

Thus, it is the issue of dissatisfaction that gave rise to the early models of conceptual change. If one were to attempt to change the alternative conception held by a student, it was believed that one would first extinguish the alternative conception in order to then substitute new conceptions (Nussbaum & Novick, 1982; Duit, 1995; Gorsky, 1994). The strongest point of view is that when presented with an anomaly, the learner would change their thinking about a concept to accommodate the new information. Discrepant events were often used early in the learning experience to provide an anomalous situation, one in which an event was presented that was contrary to the student's expectations (Driver, Guesne, & Tiberghien, 1985).

Gorsky & Finegold (1994) contended that the degree of disequilibrium from a discrepant event shown by a computer simulation could vary greatly over different examples. Some were powerful in stimulating conceptual change while others appeared to have no effect. The degree to which the disequilibrium caused the student to modify existing schemata appeared to be an underlying factor. Minor disequilibrium was equated with minor schemata changes, while more extreme disequilibrium was associated with either restructuring schemata or totally rejecting the anomalous data.

Driver, et al (1985) stated that "simply noting a discrepant event, however, is not necessarily followed by a restructuring of that student's ideas--such restructuring takes time and favorable circumstances." This disequilibrium did not always lead to conceptual change. It was often found that students did not readily give up their prior conceptions to accommodate the new information, but rejected this new conception, or accepted it as a concept to be used in certain "school" situations while retaining their initial conceptions for "real world" situations. In fact, in Gorsky & Finegold's computer simulations of discrepant events, students found some events so incompatible with their prior conceptions, that they questioned the reality of the computer generated simulation.

According to Posner et al. (1982) the use of anomalies to cause dissatisfaction with an existing conception only works when "students understand (a)why the experimental findings represents an anomaly, (b)that it is necessary to reconcile the findings with their existing conceptions, (c)are committed to the reduction of inconsistencies among the beliefs they hold, and (d)attempts to assimilate the findings into the students' existing conceptions are seen not to work." Since meeting all of these conditions is difficult at best, the authors suggest that rather than leading to conceptual change, anomalies might just as well lead to rejection of a theory or compartmentalization of knowledge to prevent a conflict from arising.

Chinn and Brewer (1993) actually delineate six possible reactions to contradictory information which can occur other than an change in conception. These include the student ignoring the data, rejecting it out right, excluding the data, holding it in abeyance, reinterpreting the data, or accepting the data only for making peripheral changes in their prior conception. Only their seventh reaction results in conceptual change.

In their review of conceptual change, Scott, Asoko, and Driver (1991) separate the use of discrepant events from other forms of inducing conflict, making the case that, historically, the intent of discrepant events was to eliminate the student's prior conception. Then a new conception could be introduced as a replacement. Duit groups all forms of conflict promotion together, whether discrepant events or conflict induced through open-ended questions, predictions, and contrasts between teacher and students or student and student. Duit then goes on to warn that while the teacher may recognize the intent of the discrepant event, the student may not see the conflict at all.

In summary, early conceptual change theory relied heavily on discrepant events as a means of not only causing dissatisfaction with a conception but causing such strong dissatisfaction that the students were willing to give up their initial conception entirely. The cause of this dissatisfaction was labeled conflict. This poses a theoretical problem. Conceptual change was thought to require conflict caused by discrepant events. But are there other means of initiating dissatisfaction which do not rely on either discrepant events, harsh conflict, or imply the elimination of prior conceptions?

From Elimination To Building On Preconceptions

These questions were partially answered when attempts at conceptual change through discrepant events were modified by later researchers who included strategies that, while still providing contrast between conceptions, also drew on what the student already knew and believed. Stavey & Berkovitz (1980) use the term cognitive conflict to describe this process in their research on children's understanding of temperature. In

other research as well, there is a shift of attention away from extinction of the preconceptions to restructuring of these conceptions (Hewson, 1981; Posner, Strike, Hewson, & Gerzog, 1982; Strike and Posner, 1992; Jensen & Finley, 1995). Strike and Posner (1992) point out that the early work in conceptual change did not recognize the importance of the interactions between prior conceptions and the new conceptions. They note that conflict may actually occur through criticism of an old schema or conception, calling into question an old model, or disharmony between two conceptions: an old and a new conception, an old conception and a new observation, or an old conception and an old observation. Thus, the concept of 'conflict' was widening and was not limited to discrepant events.

In whatever way 'conflict' occurs, it leads one to be more or less dissatisfied with one's current model, to mistrust the model to some degree, or to discount the plausibility of the initial model (Duit, 1994; Scott, et. al., 1991). Scott, Asoko, and Driver include in this category Cosgrove and Osborne's Generative Learning Model (1985) and Champagne, Gunstone, & Klopfer's (1985) Ideational Confrontation Model. In both models conflict is induced between the student and the teacher or between the student and other students, as well as through the introduction of discrepant events. Duit, on the other hand, speaks of continuous and discontinuous pathways. He contends that it is only in discontinuous pathways, in which fundamental restructuring occurs in the preconceptions of the student, that conflict occurs.

Major restructuring that requires changing the ontological category of a conception has been found to be a much more difficult undertaking than simple change within an ontological category (Chi et al., 1994). The authors define an ontological attribute as a property that an entity may potentially possess as a consequence of belonging to that category (Chi et al., 1993). In their Incompatibility Hypothesis, the

authors contend that when concepts do not require a major shift in ontological category, however, deep understanding may occur without similar difficulty.

Some researchers, however, advocate against initiating conflict at all and encourage introduction of a scientific model as another "way of knowing". Stavy (1991) used such an approach in her study on conservation of matter. She suggests that conflict may actually result in loss of self confidence and regression in students. Constructing a scientific model not intended to replace the current preconception but to coexist with it has also been suggested (Niedderer, 1987; Stavy, 1991). On the other hand, cognitive conflict has been shown to play a positive role in conceptual change when it is integrated with a constructive process (Chan, Burtis, & Bereiter, 1997). In this research Chan and Bereiter suggest that while conflict alone was not enough to cause students to change long held ideas, when students in a one-on-one situation were provided with "probe statements that maximally contraindicated their understanding" about evolution (Chan, Burtis, & Bereiter, 1997), these students performed better on posttests than students who received probes that were maximally congruent with their prior understanding. It was the authors' contention that by supplying not just a discrepant event, but also problem situations, it encouraged students to begin to seek answers and in so doing, to construct new understanding.

Stavy and other researchers have focused on the use of analogy to build on preconceptions the student already holds (Brown and Clement, 1989; Clement, Brown, & Zietsman, 1991; Gorsky & Finegold, 1994; Glynn, Doster, Nichols, & Hawkins, 1991; Mason, 1994). Analogy is generally defined as forming a representation for a less familiar concept by means of a more familiar idea or concept. Mason (1994) further describes the process of analogy as detecting the similarities between two systems and then transferring relevant information to a target (the less familiar concept). Conceptual change research has used analogy to introduce a new idea or provide a bridge between a source conception and a new idea (Brown and Clement, 1989; Stavy,

1991; Gorsky & Finegold, 1994; Glynn, Doster, Nichols, & Hawkins, 1991; Mason, 1994). Source conceptions are viewed not as misconceptions but rather naive conceptions which can be built upon with the use of scaffolding and bridging, leading to a refinement of the source conception or construction of a new conception. Dupin & Johsua (1989) further define this refinement to distinguish it from mere accumulation of new information. They state, "it does not consist of accumulating new notions upon previous ones, but of a real unceasing reconstruction of the range of knowledge." These authors point out that analogies can be used to achieve conceptual change.

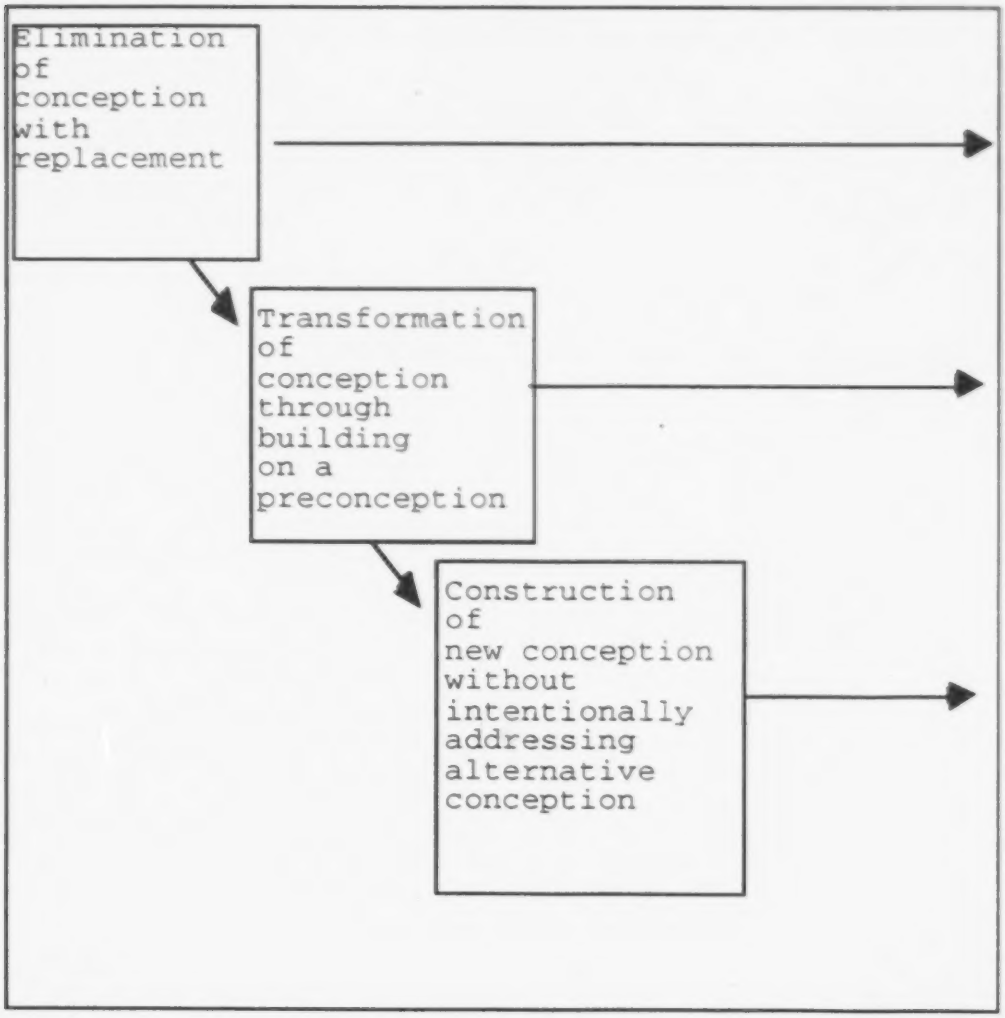
Elimination of conception with replacement
Transformation of conception through building on a preconception
Construction of new conception without intentionally addressing alternative conception

Figure I-1: Evolution of conceptual change theories

BEST COPY AVAILABLE

To summarize, the meaning of conflict has been modified over time to indicate those situations in which dissatisfaction with a preconception could lead to change without elimination of the old conception. However, some researchers advocate the avoidance of all conflict. It has been suggested that analogy may provide a means of achieving conceptual change without conflict. Figure 1 is our graphic representation of how this change in both strategies and terminology has evolved over the years. Researchers continue to disagree on how to achieve these changes. Some proponents favor the use of conflict to further conceptual change and others warn that it should be avoided. However, must all conflict be defined only in terms of major upheavals within the beliefs of an individual?

Terminology

As the strategies and sources proposed to initiate conceptual change evolved, the same terminology took on different meanings. This non-differentiation of terms leads to confusion. We suspect that disequilibrium can sometimes be based on dissatisfaction that is too mild to be called conflictual. In this paper we propose that there are milder forms of dissatisfaction in which a person feels an interesting sense of mild unease, and from which the person may experience a need to pursue some form of change. Therefore, we need a term for this unease, one that is not too harsh or too vague. For this reason, we propose two categories of unease formally referred to in the literature as conflict. We use the following definitions to distinguish between these categories:

1. Dissonance refers to a sensed internal discrepancy between a conception and another entity (observation or other conception).
   a. Strong dissonance refers to an explicit, strong incompatibility between a conception and another entity.
   b. Weak dissonance refers to a mild sensed discrepancy.

2. Discoordination refers to a sensed incompleteness of an explanation, outside the domain of dissonance (Inagaki & Hatano, 1986).

It is our belief that a broader notion of dissonance that includes both a and b above, may actually be implied by most models of conceptual change. In this paper we concern ourselves only with the first (1) of these terms, dissonance although in later papers I discuss the role of discoordination in constructed understanding (Rea-Ramirez, 1998).

The Role of Dissonance

In the area of conceptual change, while the teacher or researcher may hope that the reaction to dissonance will be in the direction of change toward a more scientifically acceptable model, this may not always be the case. As shown by Chinn and Brewer (1994), students often have great resilience to dissonance and choose to ignore or discount the source of the dissonance in favor of the already existing preconception. In addition, there may be a form of dissonance that motivates change but that does not cause extreme discord between a prior conception and a new ideas. While the term conflict appears to indicate that the student is both aware that a discrepancy exists between their alternative conception and another conception, opinion, or observation, we suggest that the term dissonance indicates something that may begin as a more implicit disquiet that can stimulate a need for action.

Berlyn (1965) believed that an optimal degree of cognitive dissonance leads to curiosity and learning. In this paper we wish to examine the possibility that the nature of change from an initial preconception may often preclude the avoidance of dissonance -- that even when the teacher does not consciously seek to foster dissonance, the mere exposure to different ways of knowing may cause some dissonance. Historically, people have referred to the dissonance as "conflict" but with a broader definition of dissonance we can possibly envision other instances where dissonance exists without harsh confrontation.

Dissonance vs. Outcomes of Conceptual Change

Historically, people have thought of 'conflict' as the strongest form of dissonance. The terms conflict and dissonance are sometimes assumed to imply an approach to conceptual change that involves eliminating or replacing an existing conception. It is important, however, to differentiate dissonance itself from the transition process or outcome of conceptual change. In conceptual change situations starting from a prior model (P.M.), M1, we hypothesize that at least four possible processes can occur (see figure 2). These include 1) discarding or eliminating the P.M. and replacing it with a new conception, 2) constructing a new model without change to the initial model, (M1 might continue to be used in practical contexts, with M2 being used in academic contexts), 3) modifying the P.M. through a transformation , and 4) constructing M2 via a change in a "copy" of M1, but the original M1 is retained for use in practical contexts. In Figure 2, 'substitution' refers strictly to an outcome where M2 now exists without M1, without saying whether that occurred via elimination or transformation. ('Replacement' on the other hand usually has a compound meaning in the literature implying both elimination and substitution).

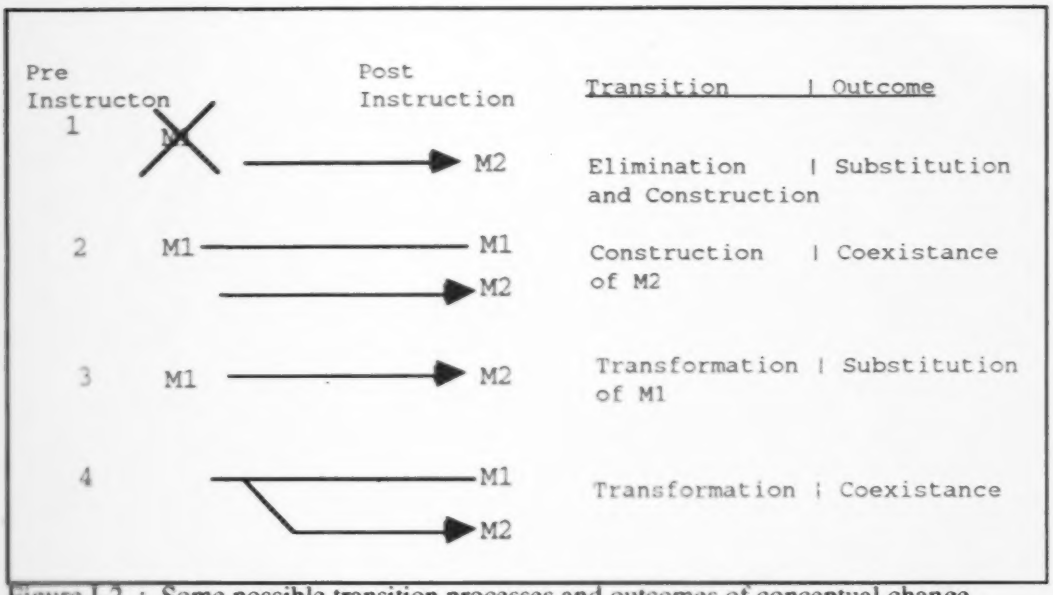

Figure I-2 : Some possible transition processes and outcomes of conceptual change from an existing conception or model, M1

Hypothetical examples of each of the four processes and outcomes help to clarify our notations. An example of Figure I-2 (1) is the alternative conceptions that students hold about the effect of a vacuum on weight. Students are confronted with a bell jar with an object inside sitting on a scale. They are then asked whether the reading will change a large amount when the air is evacuated from the bell jar. Many students believe that the reading will be significantly less indicating that weight depends on downward air pressure. This prior model may represent an alternative conception that is quite difficult to build on and the student may be best served by recognizing that it is not plausible and then building a new conception. Most students are willing to reject this idea once they see the experiment performed.

Process (2) represents a situation in which a student holds a prior conception about a topic such as sucking through a straw that is different from that taught in school. The student then finds it necessary to construct a new M2 concerning pressure differences that he/she uses in school situations but does not agree to give up M1 for

other everyday situations. In this case the student may still hold on to the belief that M1 sufficiently explains most situations but that M2 has some uses in other contexts..

Process (3) may be seen in the study of electric circuits in which many students have a prior model of a 'squirt can' battery. In this model, electric charge squirts out of either end of the battery. Through teaching strategies that employ the sources of dissonance suggested in this paper as well as other research, students may begin to transform this model into a new conceptual model that has the charge coming only out of one end -- retaining the squirting idea, but only applying it to one side of the battery. Gradually the student begins to construct a model that not only recognizes that charge comes from only one end of the battery but also that charge moves through the circuit and returns to the other battery terminal. This then, is a transformation of M1 to M2 where M1 is not strictly eliminated but slowly transformed.

Situation (4) represents a scenario in which the student has a prior model similar to that in Process (3). In this process the student undergoes a transformation of their prior model -- the squirt can battery -- developing a more complex model of electricity. However, the student still maintains the original model of a squirt can battery to explain everyday situations such as a battery that has 'run out'.

In all the situations presented as examples, dissonance between a prior conception and an new conception, or between a prior conception and a new observation, may produce an effect within the student. We suggest that dissonance can play an important potential role as a stimulus for change and knowledge construction for any of these four outcomes. In case (3) dissonance could have motivated the transformation of M1, even though M1 is not eliminated. Also, in case (2) dissonance with M1 could still have motivated the construction of M2, without necessarily eliminating M1. The same is true for case number 4--transformation with coexistence. Conflict is often associated in the literature with elimination or

replacement of existing conceptions. However for the above reasons, we feel that views that associate dissonance with elimination or replacement alone are too narrow.

Sources of Dissonance

In the past, dissonance was often associated with discrepant events as the only source of dissonance. Consistent with our suggested definitions, Table 1 lists a variety of other possible sources of dissonance. These include both (1) external sources and (2) internal sources in which the student may produce dissonance within themselves through exploration and reflection on their own knowledge. However, the external sources of dissonance need to be recognized by the student and internalized for conceptual change to occur.

Dissonance may arise from a theoretical or empirical source. Theoretical sources may originate either between students, within a student, or between the teacher's model and that of the student; whereas empirical sources include those observed by the student as in labs, demonstrations, discrepant events, computer animations, or recalled examples from practical experience in daily life.

SOURCES OF DISSONANCE	
THEORETICAL	EMPIRICAL
Model Suggested by Teacher	Observation/ Discrepant Event
Incoherence between two conceptions	Recalled Discrepant Exemplars
Student or Teacher Criticism of Conception	Described Counter Example
Student Questions	Computer Animations

Table 1: Sources of dissonance

Unlike traditional thought that relied heavily on discrepant events as the major source of dissonance, the sources in Table 1 are far more diverse. This is not a totally new idea, however. Other researchers have suggested new sources. Champagne, Gunstone and Klopfer (1985) and Basili and Sanford (1991) refer to an approach in teaching that uses both internal and external criticism and refutation as Ideational Confrontation (Duit, 1994). In this model students struggle to analyze their understanding of a conception and then interacts with other students in an attempt to justify this understanding. Others have initiated dissonance through open-ended questions (Dreyfus, Jungwirth, & Elkiovitch, 1990; Niedderer, 1987; Hewson & Hennessey, 1991; and Posner, Strike, Hewson, and Gertzog, 1982) and through experimentation and observation of labs, demonstrations, and teacher models (Niedderer, 1987; Stavy & Berkovitz, 1980; Stavy, 1991; Carey, 1989; Osborne & Wittrock, 1983; Scott, 1991; Rowell & Dawson, 1985). Jensen and Finley (1995) used historical arguments to induce cognitive dissonance for conceptual change.

It may be that the use of analogy can also be a source of dissonance. Clement (1993) reported that bridging analogies had been observed to spark interesting arguments in large group discussions. Attempts by the student to reconcile a bridging analogy for an alternative conception that is also an analogy for a target conception could possibly lead to optimal dissonance -- that is, just enough dissonance to initiate or encourage change without undue distress. Rea-Ramirez (1998) has documented dissonance between the initial conceptions of a cell and analogies suggested by both the teacher and the student.

In suggesting an analogy of a school to a cell it was hoped that some dissonance would be caused between the students previous model of a cell and a newly mapped cell construction. Early in the tutoring sessions the students were asked to draw their concept of cells. These pictures were very simplistic, usually just a circle or rectangle with a few dots or one dark central dot. All but one showed no function. So the

tutor attempted to use the school analogy to encourage the students to generate a model with more structure and function. As the students mapped features of a school to features that may be present in a cell, the tutor repeatedly had the students refer back to their initial drawing for comparison. Therefore, as students constructed this new cell with structure and function based on an analogy, they had to reconcile it with their initial model of a cell. When students experienced dissonance caused by this comparison they were propelled to consider a new model, one that might be similar to the school analogy. Most of the students could no longer rely on their initial model to explain the function that they had attributed to the analogy model. Student IV stated, "Yeah, yeah! I had those little lines but I didn't have a reason for them. Now I have a reason, you need interconnections in a cell." This is an example of an analogy being used as a source of both dissonance and construction.

External sources of dissonance, while recognizably dissonant from the teacher's view, may not be seen as dissonant by the student (Duit, 1995). That is, having a deeper understanding of a concept may allow the teacher to realize a conflict between the student's conceptual model and the scientifically accepted model. The teacher then sets up a situation in which this contrast is openly drawn. However, the students may find that their conceptual model satisfactorily explains events and relationships in the real world for them, and consequently the students do not recognize the need for another model. Attempts at introduction of external sources of dissonance may then be ignored or simply not recognized by the students. The students do not recognize dissonance since they see no reason to integrate or even entertain other information.

When rejection is the response, the teacher often intervenes to introduce other sources of dissonance that might induce the student to either question their prior model or begin to be curious about other possibilities. In research in the area of human respiration one student maintained a persistent preconception of lungs shaped like tubes (Rea-Ramirez, 1998). An activity was initiated by the tutor that was intended to show a

discrepancy between the amount of air the student believed could be held in the lungs and the actual amount. Even though the amount the student measured from his lungs was greater than could have fit in the tubes he drew, he continued to insist that it could work and was not willing to entertain another explanation based simply on this evidence. It was necessary for the teacher to introduce other strategies to produce enough encouragement and dissatisfaction with that model for him to begin to construct a new model. Therefore, promotion of dissonance through external means may not always be effective in inducing change or growth until the student has cause to internalize the dissonance. Further research in this area is now underway.

Depending on how they are handled in the classroom, none of the sources in Table 1 need necessarily be confrontational, with the possible exception of student or teacher criticism of a conception. Often the problem is just the opposite--the student fails to see a difficulty with the conception even in light of the new source of dissonance. Thus there are many sources of dissonance that are not confrontational. A key element of the use of dissonance in conceptual change is that the student is not left with mere dissatisfaction with a prior model but is simultaneously helped to criticize and construct new mental models. The major factor in this model is the constant reliance on the student's reactions, need for support, questioning, and reasoning that is going on between the teacher and student, between students, and within the individual student. Also important is the continuous return to prior models to make comparisons, revisions, or additions and the reliance on building on preconceptions. The teacher's role in the students' conceptual construction is the continuous monitoring to determine when, where, and how much dissonance is needed to obtain optimal reaction in the student. It should be pointed out again, however, that while some of the sources of dissonance originate with the teacher, dissonance itself was internal - within the individual student.

In summary, we have tried to separate potential sources of dissonance (Table 1) from an actual state of internal dissonance itself, and from the outcomes of dissonance in the form of conceptual change (Figure I-2). The sources of dissonance may arise internally, within the student, or externally, such as between other students and/or the teacher, or from observation. These sources do not necessarily need to involve harsh confrontation; thoughtful consideration of a discrepant event, analogy, counterexample, or alternative model may lead to curiosity and growth rather than discouragement. The conditions under which this occurs is a very important area for future research.

Whether the ultimate outcome of dissonance is elimination, modification, or coexistence of two models, may depend more on the way dissonance is employed by the teacher and the student, but it is not necessarily the case that dissonance must lead to elimination of an existing conception to be effective.

Conclusion

There may be some in science education who continue to look skeptically at conceptual change strategies because they still associate the term conflict with elimination or replacement only. However, views that equate dissonance with replacement alone may be too narrow. Additionally, it is not the case that all teaching strategies that use dissonance are aimed at the eventual eradication of most of the student's preconceptions. In fact, since the outcomes of dissonance vary, (see Figure I-2) dissonance should not necessarily be equated with elimination or harsh didactic confrontation. Certain carefully chosen discrepant events may actually be sources of just enough dissonance to encourage change; and this need not require the complete elimination of a prior model.

Dissonance does not just arise from discrepant events; it may also arise from analogies, competing models, and recalled examples, and these may originate internally within the same student, or externally from other students or sources of authority. There are many sources of dissonance, both internal and external, that may work

together to cause conceptual change (see table 1); these include discrepant events, analogies, familiar exemplars, and criticisms, as well as internal reflection. Whatever the source, however, it may be this dissonance that causes the student to engage in some internal struggle, to seek consonance. This, in turn, may lead to conceptual change. Such dissonance has been observed in some successful approaches even where researchers have indicated a desire to avoid what they call "conflict".

It may be that dissonance is, to some extent, unavoidable in learning situations where a prior model exists and could provide a useful tool in promoting conceptual change when used with care. Therefore, it is important to look for optimal ways to use dissonance before dismissing it as a strategy. That is not to say that one discrepant event, bridging analogy, or other source of dissonance is always, or even usually, sufficient. In our opinion, not nearly enough empirical work has been done to reach conclusions about whether all forms of dissonance are helpful or harmful in general; nor has this been done for specific strategies such as discrepant events. It may be that multiple strategies are needed to provide the scaffolding necessary for conceptual change to occur and this also needs further empirical investigation.

A number of studies have shown learning through the use of various levels of conflict (dissonance) (Chan et al, 1997; Dreyfus, Jungwirth, & Elkiovitch, 1990; Jensen and Finley, 1995; Niedderer, 1987). At the same time, other studies such as those of Stavy express valid concerns about the affect of conflict on students' self concept. However, at this time there appears to be enough support of conceptual change through the use of dissonance that we should not be asking whether or not to ban dissonance, but when and how to best use dissonance.

References

Basili, P. A., and Sanford, J. P. (1991). Conceptual change strategies and cooperative group work in chemistry. Journal of Research in Science Teaching, 28(4), 293-304.

Berlyne, D. E. (1965). Structure and direction in thinking. New York: Wiley & Sons.

Brown, D. E., and Clement, J. (1989). Overcoming misconceptions via analogical reasoning: Abstract transfer versus explanatory model construction. Instructional Science, 18, 237-261.

Caravita, S., and Hallden, O. (1994). Re-framing the problem of conceptual change. Learning and Instruction, 4, 89-111.

Carey, S. (1985). Conceptual change. Cambridge, MA: MIT Press.

Carey, S. (1989). An experiment is when you try it and see if it works: A study of grade 7 students' understanding of the construction of scientific knowledge. International Journal of Science Education, 11(special issue), 514-529.

Champagne, A. B., Gunstone, R. F., & Klopfer, L. E. (1985). Instructional consequences of students' knowledge about physical phenomena. In L. H. T. West and A. L.April 6, 1998 Pine (Eds.), Cognitive structure and conceptual change. New York: Academic Press.

Chan, C., Burtis, J., & Bereiter, C. (1997). Knowledge building as a mediator of conflict in conceptual change. Cognition and Instruction, 15(1), 1-40.

Chi, M. T. H. (1992). Conceptual change within and across ontological categories: Implications for learning and discovery in science. In R. Giere (Ed.), Minnesota studies in the philosophy of science: vol. 15. Minneapolis, MN: University of Minneapolis Press.

BEST COPY AVAILABLE

Chi, M. T. H., Slotta, J. D., & de Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. Learning and Instruction, 4, 27-43.

Chinn, C. A., & Brewer, W. F. (May, 1993). Theory change in response to contradictory information. Paper presented at the annual meeting of the American Educational Research Association.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. Journal of Research in Science Teaching, 30(10), 1241-1357.

Clement, J., Brown, D., & Zietsman, A. (1989). Not all preconceptions are misconceptions: finding "anchoring conceptions" for grounding instruction on students intuitions. International Journal of Science Education, 11, 554-565.

Cosgrove, M., & Osborne, R. (1985). Lesson frameworks for changing children's ideas. In R. Osborne & P. Freyberg (Eds.), Learning in science: The implications of children's science. Portsmouth, NH: Heinemann.

diSessa, A. A. (1988). Knowledge in pieces. In G. Forman and P. B. Pufall (Eds.), Constructivism in the computer age. Hillsdale, NJ: Erlbaum Associates.

Dreyfus, A., Jungwirth, E., & Eliovitch, R. (1990). Applying the "cognitive conflict" strategy for conceptual change --some implications, difficulties, and problems. Science Education, 74(5), 555-569.

Driver, R. (1973). The representation of conceptual frameworks in young adolescent science students. DAI. University of Illinois.

Driver, R., Guesne, E., & Tiberghien, A. (1985). Children's ideas in science (pp. 6). Philadelphia, PA: Open University Press.

Duit, R. (1995). Conceptual change approaches in science education. Paper presented at the Symposium on conceptual Change. Friedrich-Schiller University, Jena, Germany.

Dupin, J. J., and Johsua, S. (1989). Analogies and "modeling analogies" in teaching: Some examples in basic electricity. Science Education, 73(2), 207-224.

Duschel, R., Smith, M., Kesdou, S., Gitomer, D., & Schauble, L. (April, 1992). Assessing student explanations for criteria to format conceptual change learning environments. Paper presented at American Educational Research Association, San Francisco, CA.

Glynn, S., Doster, E., Nichols, K., and Hawkins, C. (April, 1991). Teaching biology with analogies: Explaining key concepts. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Glynn, S. (1995). Learning science meaningfully: constructing conceptual models. In S. Glynn & R. Duit (Eds.), Learning science in the school. Mahwah, NJ: Erlbaum.

Gorsky, P., and Finegold, M. (1994). The role of anomaly and of cognitive dissonance in restructuring students' concepts of force. Instructional Science, 22, 75-90.

Grandy, R. E. (April, 1990). On the strategic use of history of science in education. Paper presented at the annual meeting of the American Educational Research Association, Boston.

Hewson, P. W.(1981). A conceptual change approach to learning science. European Journal of Science Education, 3, 383-396

Hewson, P. W., and Hennessey, M. G. (1991). Making status explicit: A case study of conceptual change. In R. Duit, F. Goldberg, & H. Neidderer (Eds.), International Workshop - Research in Physics Learning: Theoretical Issues and Empirical Studies. University of Bremen.

Hewson, P. W., & Hewson, M. G. (1992). The status of students' conceptions. In R. Duit, F. Goldberg, & H. Niedderer, (Eds.), Research in physics

learning : Theoretical issues and empirical studies. (pp. 59-73). Kiel, Germany: Institute for Science Education at the University of Kiel.

Inagaki, K., & Hatano, G. (1986). Motivation for understanding. Technical Report.

Jensen, M. S., & Finley, F. N. (1995). Teaching evolution using historical arguments in a conceptual change strategy. Science Education, 79(2), 147-166.

Jung, W. (1993). Hilft die Entwicklongspsychologie dem Naturwissenschaftsdidaktiker. In R. Duit, & W. Graber, (Eds.), Kognitive entwicklung und lernen der naturwissenschaften. Kiel, Germany: Institute for Science Education at the University of Kiel.

Linder, C. J. (1993). A challenge to conceptual change. Science Education, 77, 293-300.

Marton, F. (1981). Phenomenography--a research approach to investigate different understandings of reality. Journal of Thought, 21(3), 28-49.

Mason, L.(1994). Cognitive and metacognitive aspects in conceptual change by analogy. Instructional Science, 22, 157-187.

Niedderer, H. (1987). A teaching strategy based on students' alternative frameworks - theoretical concepiions and examples. In Proceedings of the Second International Seminar. Misconceptions and Educational Strategies in Science and Mathematics, 2, 360-367. Ithca, NY: Cornell University Press.

Nussbaum, J. (1979). Children's conceptions of the earth as a cosmic body: A cross age study. Science Education, 63(1), 83-93.

Nussbaum, J., & Novak, J. (1976). An assessment of children's concepts of the earth utilizing structured interviews. Science Education, 60(4), 535-550.

Nussbaum, J., & Novak, J. (1982). Alternative frameworks, conceptual conflict and accommodation: Toward a principled teaching strategy. Instructional Science, 11, 183-200.

Osborne, R. J., & Wittrock, M. C. (1983). Learning science: A generative process. Science Education, 67(4), 489-508.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66(2), 211-227.

Rea-Ramirez, M. A. (April, 1998). Developing conceptual understanding of human respiration through model building. Paper presented at the Annual Meeting of the American Educational Research Association conference, San Diego.

Rowell, J. A., & Dawson, C. J. (1985). Equilibrium, conflict and instruction: A new class-oriented perspective. European Journal of Science Education, 5, 203-215.

Scott, P. H. (1991). Conceptual pathways in learning science: A case study of the development of one student's ideas relating to the structure of matter. In Duit, R., Goldberg, F. and Niedderer, H. (Eds.), International Workshop - Research in Physics Learning: Theoretical Issues and Empirical Studies. Bremen, Germany: University of Bremen.

Scott, P. H., Asoko, H. M., and Driver, R. H. (1991). In Research in physics learning: Theoretical issues and empirical studies. Duit, R., Goldberg, F., and Niedderer, H. (Eds). Bremen, Germany: Institute for Science Education.

Spiro, R. J., Feltovich, P. J., Coulson, R. I., and Anderson, D. K. (1991). Multiple analogies for complex concepts: antidotes for analogy-induced misconception in advanced knowledge acquisition. In S. Vosniadou & A. Ortony (Eds.), Similarity and analogical reasoning. Cambridge, Cambridge University Press.

Stavy, R. (1988). Children's conception of gas. International Journal of Science Education, 10(5), 553-560.

Stavy, R. (1991). Using analogy to overcome misconceptions about conservation of matter. Journal of Research in Science Teaching, 28(4), 305-313.

Stavy, R., & Berkovitz, B. (1980). Cognitive conflict as a basis for teaching quantitative aspects of the concept of temperature. Science Education, 64(5), 679-692.

Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In Duschl, R. A., and R. J. Hamilton (Eds.), Philosophy of science, cognitive psychology, and educational theory and practice. Albany, NY: SUNY Press.

Thagard, P. (1992). Conceptual revolutions. Princeton, NJ: Princeton University Press.

Toulmin, S. (1972). Human understanding: an inquiry into the aims of science. Princeton, NJ: Princeton University Press.

Viennot, L. (1979). Spontaneous reasoning in elementary dynamics. European Journal of Science Education, 1, 205-221.

Vosniadou, S., & Brewer, W. (1987). Theories of knowledge restructuring in development. Review of Educational Research, 57(1), 51-67.

*The research reported in this study was supported by the National Science Foundation under Grant RED-9453084. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation.

BEST COPY AVAILABLE